Remarks

The Applicants have amended the Specification and Abstract to place them into contemporary form for examination and to correct minor grammatical and idiomatic errors. The Claims have been cancelled and a new set of Claims 4 – 12 have been added. Examination on the merits is respectfully requested.

Respectfully submitted,

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<u>SUBSTITUTE SPECIFICATION (Marked-Up)</u>

~~Description~~

Method for controlling bright annealing furnace

Technical field

[0001]

~~The present~~The invention relates to method of controlling the generation of white powder within a bright annealing furnace.

Background ~~Art~~

[0002]

White ash particles, often referred to as "white powder," are normally generated within a bright annealing furnace, when a heat-treated steel strip, such as stainless steel strip or the like, is heat treated in the internal furnace environment which is not to oxidize the surface of the strip.

[0003]

A large volume of white powder ~~easily~~often accumulates in the cooling zone of the annealing furnace and inside of a cooler for cooling a furnace environment gas. Continuous operation of the furnace over a long period of time results in making the thermally low conductive white powder accumulate in and adhere to the cooler and/or other related mechanisms, thus inhibiting the performance of the cooler. ~~A large~~Large amounts of cooling water ~~has~~have been used in an attempt to solve the problem~~, but~~. However, this has been found not to be the desired solution due to limitations on pump capacity.

[0004]

Moreover, because the hardness of the white powder is greater than that of the heat treated steel strip, there are cases where the steel strip is damaged as a result of excessive pressure resulting from the accumulation of the white powder on the skin-pass roller. This can adversely affect the quality of the finished product.

[0005]

Therefore, the white powder adversely affects the cooling performance of the bright annealing furnace and also has the potential to degrade the quality of the finished product. Thus, even though the bright annealing furnace is correctly installed and operated, it has been

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found necessary to periodically conduct ~~the~~ maintenance by lowering the temperature and opening the furnace for the sole purpose of cleaning out the accumulated white powder.

[0006]

The skin-pass rollers ~~must~~are also ~~be~~ removed, polished, and re-installed when this type of maintenance is conducted. Moreover, even though a reducing gas of hydrogen and nitrogen is injected into the internal furnace environment while the furnace is operating, the gradual release of oxygen atoms makes it difficult to set the residual oxygen concentration to the required value when the gas is re-injected into the furnace environment, since the internal environment is oxidized by the opening operation of the furnace for ~~the~~ maintenance. The operating yield of the bright annealing furnace is also significantly reduced because the furnace cannot be operated while the aforesaid maintenance is being conducted.

[0007]

As noted above, a conventional bright annealing furnace exhibits the shortcoming of generating a white powder which makes it difficult to maintain the cooling performance of the furnace, reduces production efficiency due to the periodic maintenance required to remove the white powder (during which the furnace may not be operated), and adversely affects the quality of the finished product. As a result of these shortcomings, it is desirable that a method of reducing the generation of white powder is invented.

~~Reference Document 1   Japanese unexamined patent publication No. 10-72624~~

~~Disclosure of the Invention~~

~~Shortcomings in the Prior Art~~

[0008]

~~The inventor, having analyzed the composition of the white powder generated within a bright annealing furnace used for mass production annealing (hereafter referred to as a production furnace), bases the present invention on the discovery that the main component of the white powder is a large volume of a boron oxide compound. In regard to the process through which the boron oxide is generated, the inventor concludes, based on his research, that the generation of the boron oxide results from a relationship between the boron in the heat treated steel strip and the residual oxygen and water within the furnace. Therefore, if the generation of boron oxide can be suppressed, the previously noted problems relating to the generation of white powder can be essentially eliminated.~~

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[0009]

~~The present invention, which has been made possible as a result of the inventor's study of the prior art technology, has the purpose of suppressing the generation of white powder within a bright annealing furnace.~~

~~Means of Resolving Shortcomings in the Prior Art~~Summary

[0010]

~~The~~A selected aspect relates to a method for controlling a bright annealing furnace ~~invention comprises a step that~~comprising establishing a partial pressure of ~~the~~ steam ~~of the internal environment~~ within the furnace ~~generating the boron oxide is established~~ at less than about 1 x 10⁻⁵ to suppress generation of boron oxide. ~~More specifically, it is preferable that~~In another aspect, the partial pressure of the steam is established at a value less than about 1 x 10⁻⁵ by lowering ~~a~~the dew point of the internal furnace environment.

[0011]

~~It is preferably to~~The method can also include a process wherein a gas having a hydrocarbon component is introduced into the internal environment of the bright annealing furnace to reduce ~~a~~the water vapor pressure to a value of less than about 1 x 10⁻⁵ by lowering the dew point of the internal environment within the furnace.

[0012]

~~It is preferably to~~The method can further include another process wherein a chemical compound having a carbon component is introduced into the internal environment of the bright annealing furnace to reduce the water vapor pressure to a value of less than about 1 x 10⁻⁵ by lowering the dew point of the internal environment within the furnace.

Brief Description of the Drawings

[0013]

Fig. 1 is an Ellingham diagram showing the Gibbs standard generated free energy $\Delta G°$ of the boron oxide, the causative agent of the white powder.

[0014]

Fig. 2 is a logarithmic graph showing the relationship between the partial pressure of methane, carbon monoxide, and steam at 1,400K.

Effect of the Invention

[0015]

~~The present invention provides a method through which the generation of boron oxide may be suppressed, the boron oxide being the causative agent of the white powder.~~

~~Best Mode for Carrying out the Invention~~<u>Detailed Description</u>

[0016]

~~The following describes various embodiments of the bright annealing furnace control method invention with reference to the attached drawings. The invention has resulted from an understanding of the reasons for the generation of large amounts of white powder that collect and adhere to inside of a bright annealing furnace of the type where stainless steel and other like substances are heat treated in a internal environment which is not to oxidize surfaces of the substances, and is thus able to effectively suppress generation of the white power.~~

[0017]

<u>It will be appreciated that the following description is intended to refer to specific embodiments of the invention selected for illustration in the drawings and is not intended to define or limit the invention, other than in the appended claims.</u>

[0018]

<u>We analyzed the composition of the white powder generated within a bright annealing furnace used for mass production annealing (hereafter sometimes referred to as a "production furnace") and discovered that a main component of the white powder is a large volume of a boron oxide compound. In regard to the process through which the born oxide is generated, we believe that generation of the boron oxide results from a relationship between boron in the heat treated steel strip and residual oxygen and water within the furnace. Therefore, we believed that, if generation of boron oxide can be suppressed, the previously noted problems relating to generation of white powder can be essentially eliminated.</u>

[0019]

~~Analysis~~<u>Our analysis</u> of the components of the white powder that has collected in production furnaces up to the present time has determined that the main component of the white powder is a large amount of boron oxide component. In pursuing the source of the boron generating the boron oxide, it became apparent that the volume of boron in a steel strip before heat-treating was different than the volume after heat-treating. In other words, it was

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observed that there was a reduction in the amount of boron in the steel strip after the heat treating process was completed in the furnace.

[0020]

~~In order to~~To determine the release and dispersion tendencies of boron in steel sheet~~s~~, ~~it was~~we conducted a test to heat the steel sheet to 1,000°C in a hydrogen environment. In the case when hydrogen was obtained from a hydrogen cylinder ~~was~~and introduced to this test environment, no release or dispersion of boron was observed. The dew point of the heating environment in a general bright annealing furnace extends from -30°C to -40°C. Using the hydrogen from the hydrogen cylinder resulted in the dew point falling below −60°C~~, thus a~~. Thus, the temperature was much lower than that encountered in a production furnace.

[0021]

The results of this test demonstrated that (1) the steam partial pressure was lowered due to the low dew point, and (2) there was no oxygen source from which the boron could be oxidized. There are ~~not any~~no residual water component ~~and~~nor oxygen to react with the boron in the heat-treated steel strip, thus resulting in no release and dispersion of boron.

[0022]

Current production furnaces do not meet these conditions. In other words, ~~the inventor has~~we determined that the internal environment of ~~a~~commonly used bright annealing furnace~~s~~ ~~has~~have a high dew point and residual water and oxygen component within the furnace, and these factors ~~which~~result in the oxygen reacting with the boron within the heat treated steel strip. Boron oxide, which is the base substance of the white powder, is thus generated.

[0023]

Taking these facts into consideration, ~~the inventor was able to create the invention by deducing~~we deduced that it would be advantageous to lower the dew point in the internal furnace environment. In other words, it would be beneficial to lower the partial pressure of the steam within the internal furnace environment.

[0024]

~~Although the invention proves effective by simply lowering the dew point, there~~There are two methods by which ~~this~~lowering the dew point can be achieved[[;]]: (1) introducing a gas having a hydrocarbon component or (2) adding a chemical compound having a carbon component, to the internal furnace environment.

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[0025]

Due to the fluid state of the gas having a hydrocarbon component, the gas may be easily injected into the internal furnace environment without regard as to the type of furnace being used, thus making the invention ~~appropriate and~~ applicable to various types of bright annealing furnaces. In cases where a solid chemical compound having a carbon component is used, the chemical compound may simply be placed in the heating region of the bright annealing furnace when inspection or maintenance work is conducted. The methods specified by the invention are thus easily applied to a bright annealing furnace.

[0026]

~~Fig. 1 is an Ellingham graph showing the Gibbs standard generated free energy ΔGθ of the boron oxide which is the main component of the white powder. Fig. 2 is a logarithmic graph of a first embodiment below showing the relationship between the partial pressures of methane, carbon monoxide, and steam at 1,400K.~~
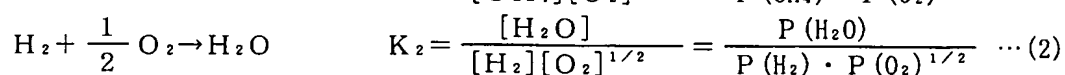
~~First Embodiment~~Example One

[0027]

The following will explain ~~the method through~~one way in which the gas having a hydrocarbon component is introduced to the internal oven environment. Any number of different gas introduction methods may be used. A reaction similar to that noted below is ~~thought~~believed to occur as a result of the hydrocarbon reacting with a minute amount of water (H_2O) and oxygen (O_2) residing within the bright annealing furnace. Explaining the reaction with methane (CH_4) as an example, decomposed CH_4 becomes carbon (C), and the H_2O is converted into carbon monoxide (CO) and hydrogen (H_2) as a result of an oxidation and reduction reaction.

[0028]

{Formula 1}

$$CH_4 + \frac{1}{2}O_2 \rightarrow CO + 2H_2 \quad K_1 = \frac{[CO][H_2]^2}{[CH_4][O_2]^{1/2}} = \frac{P(CO) \cdot P(H_2)^2}{P(CH_4) \cdot P(O_2)^{1/2}} \quad \cdots (1)$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O \quad K_2 = \frac{[H_2O]}{[H_2][O_2]^{1/2}} = \frac{P(H_2O)}{P(H_2) \cdot P(O_2)^{1/2}} \quad \cdots (2)$$

$$CH_4 + H_2O \rightarrow CO + 3H_2 \quad \cdots (1) - (2)$$

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In this reaction, K_1 and K_2 are equilibrium constants. Moreover, partial pressure P (H_2) is unrestricted at a value near 1 due to the approximately 100% concentration of H_2 in the internal environment of the bright annealing furnace. Even if the furnace operates with an internal environment other than pure H_2 (75% H_2, 25 % N_2, for example), the nitrogen (N_2) is not involved in the reaction. Also, of all components, the H_2 component comprises almost the entire environment. Thus, if error is taken into consideration, partial pressure P (H_2) may be considered as 1 (as in the following).

[0029]

With partial pressure P (H_2) being 1, converting equations (1) and (2) in Formula 1 above results in Formula 2 below.

[0030]

{Formula 2}

$$K_1 = \frac{P\ (CO)}{P\ (CH_4) \cdot P\ (O_2)^{1/2}} \quad , \quad K_2 = \frac{P\ (H_2O)}{P\ (O_2)^{1/2}}$$

from which the following is derived.

[0031]

{Formula 3}

$$\frac{K_1}{K_2} = \frac{P\ (CO)}{P\ (CH_4) \cdot P\ (H_2O)} = const\ \text{(at constant temperature)} \cdots (3)$$

[0032]

For a typical temperature up to 1,120°C in a production furnace (reference taken as the highest temperature of the material in the furnace in Fig. 1), the Gibbs standard generated free energy $\Delta G°$ of the boron oxide shown in the Fig. 1 Ellingham diagram demonstrates that it possible to effectively suppress the generation of boron oxide if P (H_2)/P (H_2O), which is steam partial pressure P (H_2O) in a 1 to 1 ratio with the dew point, is above approximatelyabout 1×10^5. Therefore, equation 3 shows that, in regard to random methane partial pressure P (CH_4) as shown in Fig. 2, the reduction of carbon monoxide partial pressure P (CO) has the effect of reducing steam partial pressure P (H_2O) to a point below 1×10^{-5} which thus makes it possible to suppress the generation of boron oxide.

[0033]

Therefore, by lowering the dew point through the introduction of a hydrocarbon-containing gas into the internal environment of a bright annealing furnace, it thus becomes possible to essentially suppress ~~the~~ generation of the causative agent of the white powder.
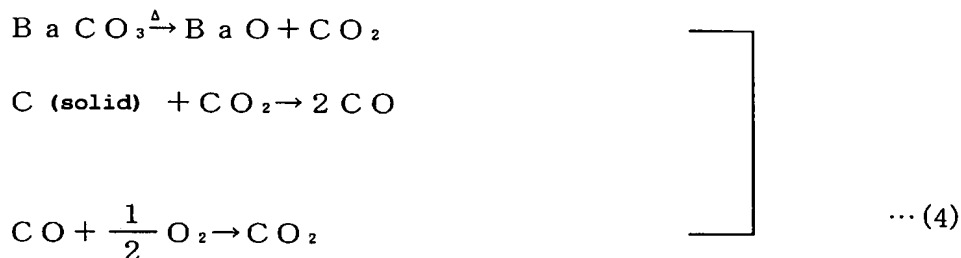
~~Second Embodiment~~ Example Two

[0034]

The following will describe a method of introducing a chemical compound having a carbon component into the annealing furnace. The reaction is described using a solid state carbon (C) as the chemical compound. A carbonate, such as barium carbonate ($BaCO_3$), and ~~a~~ solid carbon are placed in the annealing furnace to induce a reaction similar to a solid state carburizing process.
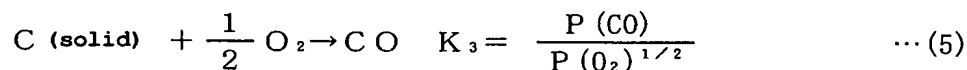
[0035]

{Formula 4}

$$\left. \begin{array}{l} BaCO_3 \overset{\Delta}{\rightarrow} BaO + CO_2 \\[1em] C_{(solid)} + CO_2 \rightarrow 2CO \\[2em] CO + \dfrac{1}{2}O_2 \rightarrow CO_2 \end{array} \right\} \quad \cdots (4)$$

[0036]

{Formula 5}

The following (equation 5) is derived from equation 4.

$$C_{(solid)} + \frac{1}{2}O_2 \rightarrow CO \quad K_3 = \frac{P(CO)}{P(O_2)^{1/2}} \quad \cdots (5)$$

[0037]

{Formula 6}

Equation 6 is derived from equation 5 and the previously noted K_2 to obtain

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$$\frac{K_3}{K_2} = \frac{P\ (CO)}{P\ (H_2O)} = 2.\ 6\ 5 \times 1\ 0^{\ 2}\ \text{(temperature at 1400K)} \quad \cdots (6)$$

[0038]

For a typical bright annealing furnace temperature up to 1,120°C, the Gibbs standard generated free energy ΔG° of the boron oxide shown in the Fig. 1 Ellingham diagram shows that it is possible to effectively suppress the generation of boron oxide if P (H_2)/P (H_2O), which is steam partial pressure P (H_2O) in a 1 to 1 ratio with the dew point, is above ~~approximately~~about 1 x 10^5. Therefore, equation 6 demonstrates that the reduction of carbon monoxide partial pressure P (CO) has the effect of reducing steam partial pressure P (H_2O) to a point below 1 x 10^{-5}, thus making it possible to suppress the generation of boron oxide.

[0039]

Therefore, by lowering the dew point through ~~the~~ introduction of a chemical compound having a carbon component into the internal environment of a bright annealing furnace, it becomes possible to essentially control ~~the~~ generation of the causative agent of the white powder.

~~Brief Description of the Drawings~~

[0040]

~~Fig. 1 is an Ellingham diagram showing the Gibbs standard generated free energy ΔG° of the boron oxide, the causative agent of the white powder.~~

~~Fig. 2 is a logarithmic graph showing the relationship between the partial pressure of methane, carbon monoxide, and steam at 1,400K.~~